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IMPACT STRENGTH, WATER ABSORPTION AND CHEMICAL RESISTANCE OF UNTREATED AND TREATED CORDIA DICHOTOMA FIBER/POLYESTER COMPOSITE

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ABSTRACT

The effects of alkali treatment on the impact strength, water absorption, and chemical resistance properties of Cordial-Dichotoma natural fiber/polyester composites, were studied. Alkali treatment (5% NaOH) was used to improve the interfacial bonding between the matrix and the reinforcement. The composites were fabricated using hand lay-up technique. By reinforcing Different weight contents (10%, 15%, 20%, and 25%) of the untreated and treated Cordia-Dichotoma fibers in the epoxy matrix. The impact strength, water absorption and chemical properties of the untreated and alkali-treated Cordia-dichotoma reinforced epoxy composites were investigated. The composite with 25%Cordia-Dichotoma fiber (5% NaOH alkali treated) gives improved impact strength when compared to the composite with untreated and neat epoxy matrix, showing that it has the superior bonding and adhesion of the composites. For water absorption and chemical resistance studies, acids, various solvents, and alkalis were used in the epoxy composites. This study has revealed that Alkali treated Cordia-Dichotoma reinforced composites have better resistance to water and chemicals than the untreated fiber composites.

KEYWORDS: Natural Fiber, Hand Lay-up, Impact Strength, Water Absorption & Chemical Resistance

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INTRODUCTION

The construction, use, and elimination of conventional composite structures, usually made of synthetic (glass, and carbon) fibers, are considered serious because of increasing environmental realization. In recent years, there is increasing interest in the use of natural fibers as reinforcing components for polymer matrices [1, 2]. The introduction of natural fibers in composites can provide benefits to the environment as they are biodegradable, with low density, cost - effectiveness, and rich in available as renewable resources [3]. However, the natural fibers have certain disadvantages such as degradation during processing, poor dimensional stability, and high moisture absorption makes them inappropriate for composite applications [4]. Another problem encountered in their use is fiber-matrix adhesion arising from the incompatibility between the hydrophilic natural fibers and the hydrophobic polymer matrix [5]. These problems were solved by alkali (NaOH) treatment method. This was extensively used for natural fibers used to reinforce polymer matrices. The alkali treatment method reduces the moisture-related hydroxyl groups (hydrophilic) and thus improves the fibers' hydrophobicity. This alkali treatment removes a certain amount of hemicellulose, lignin, and wax layering on the external surface of the fibers [6]. This alkali treatment, thus increases the effective surface area of fiber for matrix adhesion and also improves fiber dispersion

within the composite. After this treatment, fiber surface becomes rough and this can further improve fiber-matrix adhesion by providing additional fiber sites for mechanical interlocking. Mechanical behavior of the composite is enhanced significantly by this treatment [7]. The mechanical testing of most of the composite materials is mainly concerned with high elastic modulus, stiffness and strength. High strength is not enough for some composites to withstand severe stress in operation due to their brittle behavior. One significant property is the ability to absorb energy for structural applications [8]. The development of natural fiber composite materials is significant in the design of structural parts for automotive applications. The aim was to achieve light in weight, low production cost, and eventually reduced fuel consumption. Structural parts of vehicles such as front and rear bumpers are designed as energy absorbers to withstand an impact of 8 km/h without damage in low speed collision [9]. An investigation was carried out on reinforcing filler loading on the impact Strength of a wood plastic composite [10]. The results of this investigation confirmed that increasing the reinforcing filler loading reduces the flexural strength, tensile strength, impact strength, and elongation at break of the composite. The poor interfacial bonding between the fiber and the matrix caused the initiation of micro cracks at the point of contact, which then propagates into the matrix thereby reducing the impact strength of the composite. The study carried out to investigate the effect of alkali treatment on the Alfa fiber [11]. These results reveal that the rate of water absorption decreases after the alkali treatment on the fiber. Akil et al. [12] studied the water absorption and its effects on the pultruded jute fiber reinforced unsaturated polyester composite. The results confirmed that a water absorption pattern found to follow the pseudo-Fickian behavior. Anu Gupta [13] studied the water absorption and chemical resistance of bamboo reinforced polymer composites. This study concludes that water absorption increases with increase in fiber content and it follows Fickian behavior; chemical resistance decreases with an increase in the fiber weight ratio and was maximum for 10 weight percentage of fiber. The chemical resistance test was conducted by a few researchers and observed their behavior and found that there was a weight gain for some acids and bases meanwhile there is some weight loss also observed for few [20,21].

In the present research work, Untreated and treated Cordia-Dichotoma fibers were used as a reinforcement in polyester matrix. The aim of this work is to make environmentally-friendly composites. The effect of the reinforcement content on the impact strength, water absorption and chemical resistance of the composite were studied.

MATERIALS AND METHODS

MATERIALS

Cordia-Dichotoma fibers were collected from Dorigallu village situated near kadiritaluk, Ananthapuramu district, Andhra Pradesh. Unsaturated polyester resin, Accelerator, Catalyst was purchased from Ram composites, Hyderabad.

FIBER EXTRACTION

Cordia-Dichotoma fibers were collected from bark of tree. The water retting process was adopted for extraction of fibers from the bark. The extracted fibers were washed carefully using distilled water and then sun dried for one week to ensure maximum moisture removal.

ALKALI TREATMENT

The Cordia-Dichotoma fibers were drenched in a 5% NaOH solution at 30°C. The fibers were kept immersed in the alkali solution for 2 hours. Then washed a number of times with fresh water to remove any NaOH sticking to the fiber surface neutralized with dilute acetic acid and finally washed again with distilled water. The fibers were then dried at room

temperature for 48 h followed by oven drying at 100°C for 6 h[14].

COMPOSITE PREPARATION

The hand lay-up procedure was used for the fabrication of composites in the present research work. A glass mold having dimensions of 150 mm x 160 mm x 3mm was used to lay up the composite laminate. At first, the glass mold was covered with a Teflon sheet for easy removal of the cured laminate from the glass mold. The polyester resin, accelerator, and catalyst were mixed in the ratio of 100/1/1 by weight, respectively. Finally, the untreated and treated Cordia-Dichotoma fibers were placed in a unidirectional aligned manner and the mixture of resin was poured over them to prepare the composite laminate. Laminates, were allowed to cure at room temperature for 24 h. The cured laminates were then removed from the glass mold and post-cured in a hot air oven at 100^{o}C for 4 hours. The Untreated fiber reinforced polyester composites (U0, U10, U15, U20, and U25) of five different compositions (0 wt%, 10wt %, 15 wt %, 20 wt %, and 25 wt % fiber loading) are made. Another set of composites such as the alkali treated fiber reinforced polyester composites (A 10, A 15, A 20, and A 25) of four different compositions (10wt %, 15 wt %, 20 wt %, and 25 wt % fiber loading) are made. After the curing process, test samples are cut to the required sizes as per individual test requirements [13].

IMPACT STRENGTH

The impact strength was carried out according to ASTMD-256 standard using an IZOD impact tester. The sample size is 63.5 × 12.7 × 3 mm, while the notch length is 2.54 mm. Each composite specimen was tested by releasing a striking hammer on the impact testing machine. The energy absorbed by each composite specimen was displayed on a digital meter and the average impact energy was used to compute the impact strength of the composites [15].

WATER ABSORPTION

The ater absorption test was performed according to ASTM D-570-98. This test was conducted by immersion of composite specimens in distilled water for 10 days (240 h) to the point of saturation. The water was changed after every two days. Percentage increase in weight during immersion calculated using following equation [16].

Increase in weight [%] $=(W_a - W_b)/W_b$

Where W_a is the weight after soaking into water; W_b weight of before soaking into the water.

CHEMICAL RESISTANCE

To investigate the chemical resistance on the composites, the ASTM D 543-87 test method was considered. In this method, samples were soaked in the respective chemicals (acids, alkali's and organic solvents) for one complete day (24 h), taken out immediately, washed with distilled water, and then dried with filter papers. The dried samples were then weighed and the percentage weight loss or gain was determined. The percentage (%) weight loss or gain was determined using the following equation [17].

% Chemical resistance $=\frac{\text{Waci}-\text{Wi}}{\text{Wi}}$,

Where W_i = initial weight and W_{aci} = weight after 24 hours

RESULTS AND DISCUSSIONS

IMPACT STRENGTH

Impact test results were shown in table 1 for untreated and alkali treated composites at different fiber weights and the corresponding graph was shown in figure 1. From figure.1 it was observed that impact strength increases with increase in fiber weight. All composites show highest impact strength at 25% fiber loading while untreated composite shows higher impact strength (110.23J/m) than alkali treated composite (94.48J/m) with the improvement of about 16.67%. This could be mostly due to the reason that during the impact considerable part of energy absorption takes place through the fiber pull-out process, but after alkali treatment, due to the removal of soluble greasy contents o the fiber, strong mechanical interlocking develops between fiber and matrix, and fiber pull-out is minimized. This, in turn, will decrease the impact strength. This conclusion is supported by the increases impact strength with increasing fiber weight [18, 15].

Table 1: Impact Strength of Untreated and Alkali Treated Cordia-Dichotoma Fiber Composite

Type of Composite	Fiber Weight (%)	Impact Strength (J/m)
Pure polyester	0	23.62
Untreated fiber reinforced polymer composite	10	41.67
	15	62.99
	20	78.74
	25	110.23
Alkali treated fiber reinforced polymer composite	10	31.49
	15	47.24
	20	70.87
	25	94.48

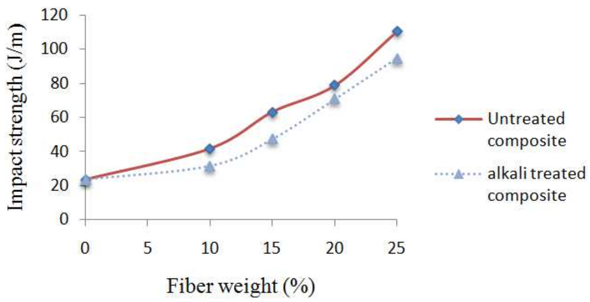

Figure 1: Effect of Fiber Weight on Impact Strength of Untreated and Alkali Treated Fiber Composites

WATER ABSORPTION

Water absorption of Cordia-Dichotoma polyester composite was shown in Table 2. The fiber absorbs water due to the presence of hydroxyl groups which absorb water through the formation of hydrogen bonding [19]. All composites show a sharp increment in water uptake at the beginning (up to 72 hours) and then remain constant around 10 days with the maximum water absorption being 5.74% and 5.69% for untreated and alkaline treated polyester composites, respectively. These results were depicted in Figure.2. The rate of water absorption was typical of Fickian diffusion, which explains that rapid water absorption takes place at the commencement of contact of matter to water; subsequently, an equilibrium point is reached. Since the composites were fabricated using hand-lay-up, water uptake was through the porosities in the fiber-matrix interface. Cordia-Dichotoma was a plantbased bark fiber, the presence of free cellulose hydroxyl groups leads to

water uptake. The highest percentage weight of water uptake was 5.74 %. This low percentage water absorption is attributed to the hydrophobic nature of polyester resin and alkaline treated polyester composite shows the lower water absorption rate because alkali treated fiber reduces less hydrophilic as numbers of hydrophilic hydroxyl groups reduce by reacting which NaOH which leads to prohibiting of water from the substrate.[19, 15]

Table 2: Water Absorption of Untreated and Alkali Treated Fiber Composites

Hours	Alkali Treated Fiber Polyester Composite(A)					Untreated Fiber Polyester Composite(U)			
Fiber weight (%)	U0	A10	A15	A20	A25	U10	U15	U20	U25
0	0	0	0	0	0	0	0	0	0
24	0.0000	0.8403	1.6529	2.4390	0.6993	1.3333	2.4096	3.4483	1.0638
48	1.4493	2.5210	2.4793	4.0650	3.4965	2.6667	3.6145	4.5977	2.1277
72	2.8986	3.0210	3.6058	4.8780	4.0951	2.6967	3.9145	5.0977	3.1915
96	2.8986	3.3613	4.1322	4.8780	4.5951	2.6667	4.3193	5.5471	3.5915
120	2.8986	3.3613	4.1322	5.0911	4.8951	2.6667	4.5193	5.7471	4.2553
144	2.8986	3.3613	4.1322	5.6911	5.5944	2.6667	4.8193	5.7471	4.2553
168	2.8986	3.3613	4.1322	5.6911	5.5944	2.6667	4.8193	5.7471	4.2553
192	2.8986	3.3613	4.1322	5.6911	5.5944	2.6667	4.8193	5.7471	4.2553
216	2.8986	3.3613	4.1322	5.6911	5.5944	2.6667	4.8193	5.7471	4.2553
240	2.8986	3.3613	4.1322	5.6911	5.5944	2.6667	4.8193	5.7471	4.2553

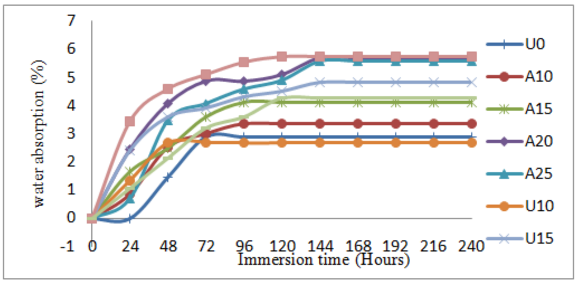

Figure 2: The Effect of Immersion Time on Water Absorption Properties of Composites

CHEMICAL RESISTANCE

Figure 3 Shows the percentage of chemical absorption of Cordia-Dichotoma polyester composite for various samples. Chemical resistance analysis was used to study the ability of the composite to withstand when contact with chemicals such as HCL, HNO_3, CH_3COOH, NaOH, NH_4OH, Na_2CO_3, C_6H_6, CCl_4 and C_7H_8. The effect of chemicals on the polyester matrix, untreated and alkali treated fiber reinforced composites was tabulated in Table 3. From the table, it was noticed that for the pure polyester matrix and Cordia-Dichtoma composites, some weight gain or loss was noticed after immersion in different chemicals. It can be observed that the polyester matrix has better resistance to chemicals than the Cordia-Dichotoma fiber composites. It was also observed that chemical resistance decreases with an increase in the fiber weight. This decrease in chemical resistance is due to exposure of more fibers to chemicals. However, the composites still have sufficient chemical resistance. It has been observed that the alkali treated fiber composites have better resistance to chemicals than the untreated fiber composites. This is due to better bonding between the alkali treated fibers and the polyester matrix, which gives the composites better resistance to chemical dispersion. Based on this study, these composites can be considered for agricultural, automotive (interior parts), and domestic household applications [13].

Table2: Chemical Resistance of Untreated and Alkali Treated Fiber Polyester Composite

Chemicals	Untreated Fiber Composite					Alkali Treated Fiber Composite			
Fiber Weight (%)	U0	U10	U15	U20	U25	A10	A15	A20	A25
HCL (10%)	1.2048	0.8621	0.8849	2.102	2.3944	0.6402	0.8304	1.3605	2.3143
HNO_3 (40%)	-0.8791	1.5094	1.5652	1.6393	1.7483	1.0949	1.5385	1.5837	1.6835
CH_3COOH (8%)	0.2632	0.9677	1.7431	2.4409	2.5179	0.8444	1.2956	1.4673	2.3283
NaOH (10%)	-0.1136	0.283	1.5833	1.6393	1.6667	1.2837	1.4192	1.4639	1.5806
NH_4OH (10%)	0	2.9091	3.1304	3.5821	4.1135	-1.0363	2.2379	3.5551	3.9791
Na_2CO_3 (20%)	0.6849	0.2885	0.7692	2.2689	2.446	0.2678	0.4723	0.8938	2.2518
C_6H_6	0.3264	0.5123	0.7201	0.8169	1.2074	0.3937	0.5767	0.6719	1.0913
CCl_4	0.2755	0.6135	0.6855	0.8491	1.1331	0.4184	0.5051	0.7955	0.8222
C_7H_8	0.1401	0.6148	0.7682	0.9788	1.3475	0.4932	0.5348	0.6985	0.9288

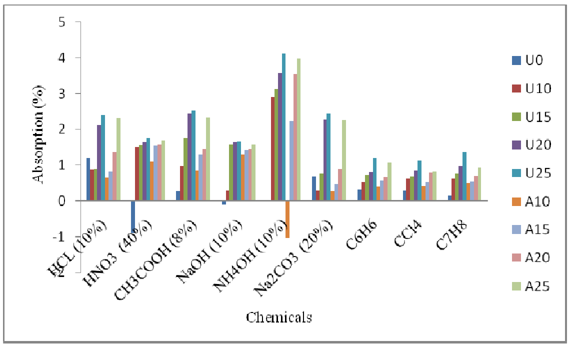

Figure 3: Chemical Absorption of Untreated and Alkali Treated Fiber Polyester Composite

CONCLUSIONS

In this study, the effect of Cordia-Dichotoma (untreated and treated) fiber content on impact strength, water absorption and chemical resistance behavior of the polyester composites were investigated and the subsequent conclusions were derived:

- Cordia-Dichotoma fiber reinforced polyester composites has been fabricated using hand lay-up method.
- Impact strength was increased with the increase in fiber weight. However, Impact strength of untreated fiber composite (110.23 J/m) were superior when compared with the alkali treated fiber composite (94.48 J/m).
- Chemical resistance decreases with increase in fiber weight and was a maximum of 25 wt% fibers. Treated fiber composites posses more chemical resistance than the untreated fiber composite. Untreated composite has shown maximum absorption for NH_4OH 4.11 %). Treated composite shown highest absorption for NH_4OH (3.97 %). However, pure polyester has no weight gain or loss was observed when immersed in NH_4OH.
- Water absorption increases with increase in fiber weight and it will follow Fickian behavior. Untreated fiber composite uptake more water than the treated fiber. The basis is untreated fibers have hydrophilic in nature.

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